

THE SIGNIFICANCE OF STANDARDIZATION IN THE DEVELOPMENT OF THE MACHINE-TOOL INDUSTRY: THE CASES OF JAPAN AND CHINA* (PART I)

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I. *Appropriate Technology and Standardization in Late-industrializing Countries*

1. *Some Key Problems and Our Viewpoint*

The current level of development of Japan's machine-tool industry is truly amazing, particularly when one remembers the poor quality of Japanese machine tools in the prewar period. Japan is now one of the major machine-tool producing countries in the world, with more than one third of her production exported to foreign countries, mainly to the U.S. market. Among Japanese machine tools, so-called multi-operation-combined machines with automatic tool-changers, such as the numerically computer-controlled (NC) lathe, the machining center and the transfer machine, have had the overwhelming competitive power in the international market since the mid-1970's.

To explain this almost incredible development of the Japanese machine-tool industry, two factors are often pointed out, that is, (1) technical tie-ups with advanced foreign ma-

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chine-tool makers in the 1950's and 1960's, and (2) the evolution of specialization within the industry, and particularly the development of the parts industry in the same period. No one can deny the significance of these direct factors in fostering the competitive power of the machine-tool industry in postwar Japan. Yet they do not clarify certain more fundamental aspects of the success story, since one cannot avoid raising the following questions: Why was it already technically possible immediately after World War II to undertake licence agreements with foreign makers, the most typical form of technical tie-ups in those days?; And, although the development of the parts industry and specialization was, we consider, greatly promoted by the development of Japanese Industrial Standards (JIS) and various company standards, as well as by the quality control (QC) movement, was the basis for such quality-improvement policies constructed abruptly after World War II?

Without a sufficient technical basis on the part of Japanese machine-tool factories, it would have been almost certainly impossible to conduct technical tie-ups of the licence agreement form with foreign advanced makers. Moreover, it usually takes a long time for the effects of industrial standards to diffuse throughout an industry. In other words, one cannot imagine the rapid development of the machine-tool industry in postwar Japan occurring without the establishment of a sufficiently strong basis of development in the prewar period. The study of the wartime development of the industry is, therefore, indispensable for understanding the recent development.

When we consider the economic problems of postwar Japan, in general there exist two different, even mutually opposing, opinions concerning the role the wartime economy played in the long run economic development of Japan: One view sees the wartime economy as an economic vacuum or an obstacle to economic growth; the other stresses the continuity of economic development, and emphasizes the wartime contribution to the development of the so-called heavy industries. As will hereafter become clear from our analysis, our perspective concerning the wartime economy is akin to the latter view.¹ Nevertheless, concrete studies of the machine-tool industry in wartime Japan have so far been quite few, despite the availability of at least fragmentary information and data. To cast a little light on this largely deserted area is one of our chief analytical purposes.

But a much more important aim of the present paper is to clarify the significance of industrial standards in improving the quality of so-called "appropriate technology" through specialization and market expansion in the late-industrializing country. For the machine-tool industry of Japan, the wartime period meant a period of extrication from an almost complete dependence on foreign technology. To take the point a step further, this extrication was possible only through the improvement of low-quality imitative technology, an improvement which could be realized particularly by enhancing industrial standards.

In the case of late-industrializing countries, the machine-tool industry is usually based on secondhand or imitative technology—"appropriate technology" under our definition.

¹ This standpoint does not at all imply any justification for Japan's invasion of Asian countries in this period. Rather, our analysis will reveal the absurdity of the Fifteen-year War from the viewpoint of basic industry's role in military production. We regret that this area is almost virgin soil as a facet of economic history as the result of a general avoidance of ideological risks. The term "Fifteen-year War" is often used in Japan, instead of the Second World War or the Pacific War, particularly when Japan's invasion in China *after 1931* is emphasized, since the emphasis of the latter two terms is rather located in the war against the United States and other Western countries after 1937 or 1941.

To upgrade this technology is, thus, a serious and urgent problem for such countries, since the machine tool as a machine for making machines, when coupled with the "copying principle," introduces an enormous cumulative effect to the machinery industry as a whole. Thus the machine-tool industry is in general very sensitive to quality improvement of machine-tools themselves, and is, as a result, one of the industries which most distinctly reflects the benefits of fixing industrial standards. This is one of the reasons we have chosen the machine-tool industry to consider the problem of the upgrading of appropriate technology.

Another important aim of this paper is to evaluate the present stage of development of the Chinese machine-tool industry from the viewpoint of standardization policy, based upon the Japanese experience. This measurement or comparison may be justified on the following two counts. First, the patterns of historical development of the machinery industries of Japan and China are quite similar. For instance, compared with other machinery industries such as the textile machinery and the ship-building industries, development of the machine-tool industry was relatively late-starting in both countries, and its competitive power was also extremely weak in both cases.²

Secondly, the urgent tasks facing the machine-tool industry in present-day China are broadly recognized as being the upgrading of product-quality and the overcoming of imitative technology. In other words, our comparison of the Japanese machine-tool industry in the period 1931–45 with the Chinese industry in the period 1958–(83) roughly means to compare the periods of extrication from imitative technology for the two industries. In this comparison the main focus will be on the role of industrial standards as a catalyzer for upgrading product-quality. Prior to starting our discussion of the development of the Japanese machine-tool industry, it is necessary to briefly confirm the concepts of appropriate technology and standardization used in our analysis.

2. *Product Quality and Appropriate Technology*

Studies of appropriate technology, both conceptual and empirical, have greatly developed in the last two decades. Nevertheless, it seems to us that there still remains some ambiguity in the concept of appropriateness itself, and great difficulties are usually encountered in assessing the appropriateness of actual "appropriate technologies." Such a phenomenon is not surprising, since different grounds for "appropriateness," viz. rationality, can be easily justified from different standpoints for actual choices of technology.

For instance, the adoption of labor-intensive technology is frequently recommended, as a general rule, to labor-abundant countries. Such a suggestion is presumably based on the ground that cost-minimization is realized if and only if factor intensity is determined by relative factor prices (hereafter we call this idea—including its variants—the factor proportion criterion).³ However, the actual dynamic world does not ordinarily guarantee at

² For further detail, see S. Ishikawa, "The Capital-goods Sector Development: The Experience of Pre-PRC China," International Labor Organization, World Employment Program Working Paper (forthcoming), and Y. Kiyokawa, "Chūgoku sen'i kikai kōgyō no hatten to zaikabō no igi" [Development of the Chinese textile-machinery industry and the significance of Japanese cotton textile mills in China], *Keizai kenkyū*, Vol. 34, No. 1 (Jan. 1983).

³ This criterion seems to be equally introduced, implicitly or explicitly, into both the social welfare approach and the specific-characteristic approach to appropriate technology. For definitions, see Frances

all the validity of its implicit assumption, namely the existence of perfectly competitive markets. In the real world, entrepreneurs in labor-abundant countries often have to choose capital-intensive technology because of the scarcity of quality labor, or the inflexibility of production coefficients. Those choices are, then, appropriate to the entrepreneurs in question from their own micro-standpoints. What is more, such a choice of capital intensive technology is usually reasonable in order to more quickly obtain greater competitive power.

That is to say, the factor proportion criterion for choice of technology is apt to include some difficulties. First, the criterion is essentially static, and is implicitly premised on comparative advantage theory with Heckscher-Ohlin-type assumptions. Policy implications derived from it are, thus, often unrealistic in the actual, dynamic world. Secondly, we are inclined to consider the practical possibility of modification of specific technologies relatively small. This is particularly the case for the core part of modern technology. Thus, in less developed countries, the transformation from capital-intensive to less capital-intensive technology frequently means conversion to a less-efficient technology or a technology with less competitive power.

Thirdly, the choice of technology should not be confused with the choice of industry. Even though capital-intensive technology is extensively introduced, the equilibrium factor price ratio will not be destroyed if a suitable policy for expansion of labor-intensive industry (or labor-intensive technology in the same industry) is adopted at the same time. In this sense, problems in the choice of technology are best discussed in combination with the choice of industry. Fourthly, it should be kept in mind that optimality on the macro level almost always differs from optimality on the micro level, as the conditions for perfect aggregation are never satisfied in the actual, non-homogeneous world. The choice of capital-intensive technology in a country with abundant labor is, therefore, not always inappropriate. Rational reasons for the selection are to be generally found, so long as the entrepreneur made the choice from his own viewpoint based on reasonable expectation. In other words, each of these considerations suggests that the factor proportion criterion may provide neither a sufficient nor a necessary condition for appropriate choice.

Yet the criterion may, on the other hand, have some legitimacy in the short-run in the static world. For instance, those who adhere to this criterion typically suggest labor-intensive technology for labor-abundant countries to maximize the employment effect of technological choice. This suggestion is quite reasonable from the viewpoint of solving the unemployment problem, which is one of the most serious problems in many less developed countries today. It is, however, quite doubtful whether or not labor-intensive technology is the best policy for solving serious unemployment in the long run in the dynamic world, since such technology usually has little competitive power, and poses difficulties in embodying the outcomes of recent technological progress. That is, even when the primary objective function is common, the concept of appropriateness may still differ according to various conditions in the real world.

To sum up, the foregoing discussion implies the impossibility of determining the unique appropriateness as an *ex-ante* concept in the complexity of the actual world. All of the

Stewart, "Macro-policies for Appropriate Technology: An Introductory Classification," A.T. International, Working Paper, 1983. See also Lawrence White, "The Evidence on Appropriate Factor Proportions for Manufacturing in Less Developed Countries: A Survey," *Economic Development and Cultural Change*, Vol. 27, No. 1 (Oct. 1978).

adduced phenomena, on the contrary, suggest that we adopt some *ex-post* concept for more fruitfully measuring the appropriateness of chosen technology. More specifically, it appears necessary to introduce a new point of view on market performance in terms of competitive power, as considering the problems of appropriate technology in the dynamic, long-run framework.⁴ We consider that the appropriateness of chosen technology should be conceptually measured by an increase in competitive power or efficiency under this view.

The suggested approach is particularly effective in examining the problem of upgrading of appropriate technology. In any case, the factor proportion criterion is unsuitable for assessing the adapted quality of products produced by appropriate technology, despite the fact that quality adjustment is one of the most significant and unique characteristics of appropriate technology. It should be borne in mind that almost all cases of appropriate technology, which are usually a combination of modern and indigenous technology, give rise to lower-quality products than does the original production method.⁵

As is well known, price is in general a function of quality, that is, it bears a trade-off relationship to the latter. But although lower-quality products with cheaper prices might have reasonable competitive power in the market, much of the appropriate technology in less developed countries unfortunately produces lower-quality products with relatively higher prices. The possibility of upgrading product quality, hence, is the most crucial factor for strengthening the competitive power of appropriate technology.

It is true that, in judging the appropriateness of "appropriate technology" from the viewpoint of market performance, it is difficult to identify competitiveness of quality due to purely technological factors from that due to the market conditions. However, the central issue is not the identification of technological factors but the competitive power of appropriate technology itself under actual market conditions. It is, furthermore, noteworthy that the general technological level in an economy ordinarily is in a kind of pseudo-equilibrium with the developmental level of its markets in the long-run. As the result, the quality-price relationship is in general determined by the total condition under given various circumstances. In other words, the relationship should be grasped against the background of interaction between technology and the market. This is the main reason we analyze the appropriate technology problem from the viewpoint of the development of national standards, since the latter has a great impact on both technological level (and ultimately the product quality) and market size (and ultimately specialization).

⁴ Hence, the competitive power of appropriate technology should be interpreted not as the criterion for judging appropriateness but as an indicator for measuring the validity of appropriate technology. Hereafter, our term "appropriate technology" is interchangeable with the conventional term "intermediate technology" in the sense that our appropriateness is measured only *ex-post* by long-run competitive power in the market.

⁵ For the concept of appropriate technology producing a lower-quality product (i.e., lower-quality technology), see S. Ishikawa, "Appropriate Technologies: Some Aspects of Japanese Experience," in *Appropriate Technologies for Third World Development*, ed. by Austin Robinson, London: Macmillan, 1979. Imitative technology of foreign one is usually a typical example of appropriate technology of lower quality resulting from adaptations. But it may retain competitive power through a price adjustment to quality. Although the flexibility of production coefficients is rather small in practice, the flexibility of price and quality adjustments may be considered fairly great.

3. Two Types of Standardization and Their Economic Effects

As is shown in Table 1, standardization has a close relationship with industrialization. That is, more industrialized countries appear to have, as a general tendency, more national standards. But a few comments are warranted together with some additional information. First, the numbers of national standards in socialist countries are apt to be relatively greater for a given technological level. This characteristic, however, was not applicable to China until recently.

Secondly, India is an exception to the general rule, the number of her standards being comparatively large, relative to the degree of industrialization of her manufacturing sector. This fact suggests that while industrial standardization may be a necessary condition for promoting industrialization, it is not a sufficient condition. To be more specific, while an increase in industrial standards promotes technological levels, industrial standards cannot be fixed without taking into account existing technological levels and market conditions, because overly sophisticated standards lose some of their effectiveness.

Thirdly, national standards are only a part of the industrial standard system which consists of three different levels of standards, viz. (1) national standards; (2) group standards; and (3) company standards.⁶ As is indicated by the case of the U.S., the relatively small number of national standards does not, *ipso facto*, imply the underdevelopment of industrial standardization, because a country may have adequate company or group standards. Generally speaking, early-industrializing countries have accumulated a wide range of company and group standards in their long histories of industrialization, while national standards

TABLE 1. INCREASE IN NATIONAL STANDARDS FOR DIFFERENT COUNTRIES

Country	Abbreviation of Standard Title	Year of Establishment	Number of Standards (Year)		
			(1935-40)	(1959)	(1978)
1. Japan	JIS ^{a)}	1921	627	4,835	7,220
2. China	GB ^{b)}	1958	(45) ^{c)}	174	1,467
3. India	IS	1947	—	1,119 ^{d)}	9,710
4. Germany ^{e)}	DIN	1917	9,800	10,411	18,000
5. U.S.A.	ANSI ^{f)}	1918	398	1,771	9,092
6. U.K.	BS	1901	740	2,734 ^{g)}	7,800
7. France	NF ^{h)}	1918	1,300	4,750	10,465
8. U.S.S.R.	GOST	1923	8,238 ⁱ⁾	6,686	22,120

Notes: a) Previously JES and JES(T). T, temporary; b) Many "Ministry Standards" existing; c) Republic of China (CSA) tentatively fixed after 1934; d) Figures for 1958; e) After WW II, DIN applies to West Germany only; f) Previously ASA: Many group standards existing; g) Figures for 1958; h) Previously AFNOR; and i) The number is for the previous standards known as OCT.

Sources: 1) 1935-40; Nihon-kikai-gakkai, *Nihon kikai kōgyō 50-nen shi* (1949), pp. 1140-41.
 2) 1959; Kōgyō-gijutsuin, *Waga koku no kōgyō hyōjun-ka* (Nihon kikaku-kyōkai, 1959), p. 197.
 3) 1978; H. Furukawa (ed.), *Hyōjun-ka* (Nihon kikaku-kyōkai, 1981), pp. 102-03.

⁶ Besides these three different standards, there exist also (4) international standards, such as ISO, IEC, etc., and (5) government organization standards, such as MS (Military standards; US), NDS (National Defense Standards; Japan), JRS (Japan Railway Standards), etc. Although these are not insignificant, our analysis mainly focuses on the role of national standards as the key standards in late-industrializing countries.

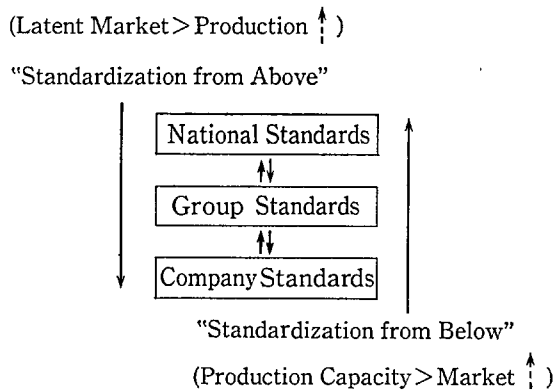
play much more significant roles in the struggle of late-coming (and also centralized) countries to catch up with the technological levels of the advanced countries.

This tendency can be generalized into two stylized standardization, namely, *standardization from below* and *standardization from above* (see Fig. 1). The former applies to standardization starting mainly with the development of company standards, which are then upgraded to group standards or national standards.⁷ In contrast with this, the latter highlights the strong leadership of government in promoting standardization through the setting of national standards, with each enterprise and the industrial world responding to the government's standardization policy to gradually develop their own standards.

What we are to examine here is the latter type of standardization, because the machine-tool industries of both prewar Japan and contemporary China are typical examples of the late-comer type, and both countries have in fact followed the pattern of government-initiated standardization. *Standardization from above* is particularly important in those countries where imitative or transferred technology is playing a dominant role in industrial technology, since government policies of standardization can comparatively easily foster the adaptation and subsequent upgrading of imported technology.

At any rate, standardization is indispensable for improving the quality of adapted foreign technology, which is usually degraded in the process of being transformed into a type of so-called appropriate technology. Furthermore, in the case of imported technology, the timing of standardization is somewhat delicate. It can be pointed out here that it is best located at a rather early stage prior to the rapid diffusion or imitation of the technology, since most transferred technologies have already been perfected in their home countries. If standardization is realized after the diffusion of imported technologies, divergent systems

FIG. 1. TWO TYPES OF STANDARDIZATION



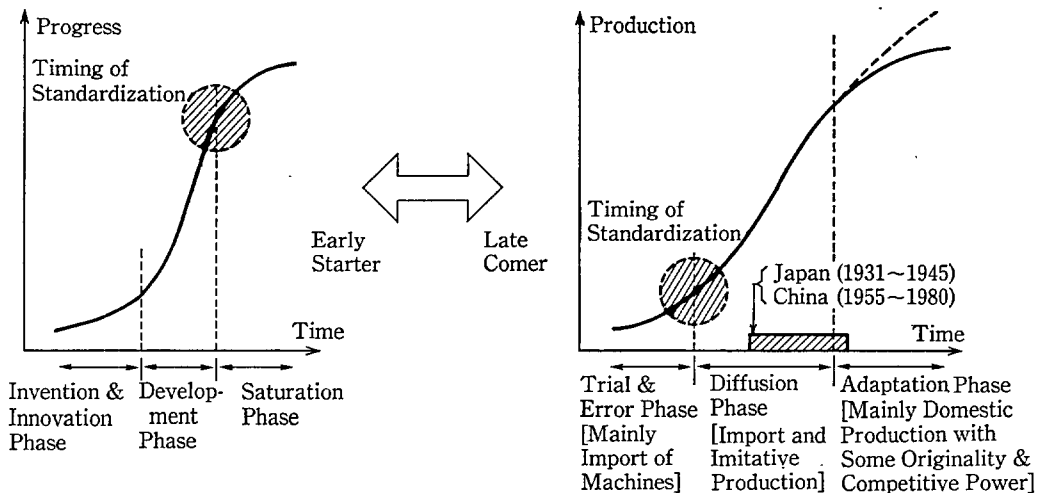
Note: "Group standards" means standards fixed by an industrial or academic association, etc.

⁷ Hence, we may also call *standardization from above* and *standardization from below*, national-standard-leading standardization and company-standard-leading standardization, respectively. The former is very powerful for fostering production capacity, particularly when a production level is low relative to latent market size. On the other hand, the latter is one of the effective means of expanding the market through increasing efficiency when a market size is small relative to production capacity. In the case of the Japanese machine-tool industry, the switch from the former to the latter can be considered to have occurred after 1970 in parallel with the increase in the industry's exports.

of technologies will prevail within single industries, causing great subsequent disorder.⁸ Fig. 2 depicts the stylized difference in the ideal timings of standardization for the cases of self-developed and imported technologies.

The timing of standardization cannot be discussed separately from the benefits of industrial standards. The essence of standardization consists in increasing interchangeability and simplicity stemmed from setting up a standard.⁹ Standards primarily promote specialization which give rise to improvement in and stabilization of quality, and mass-production which stimulates market expansion through cost reduction. Some other effects of standardization may also be pointed out. For instance, it may lead to smaller inventories of parts, and more strict inspection and quality-control of products. Repairs and maintenance usually become much easier with standardization. Furthermore, fixing standards implies in general to lessen the burden of designing, and invites the shifting of the firm's

FIG. 2. THE TIMING OF STANDARDIZATION



Notes: 1) For the basic idea, see J. Gaillard, *Industrial Standardization*, H.W. Wilson Co., 1934.

2) For the details of phase demarcation, see Y. Kiyokawa, "Gijutsu kakusa to dōnyū-gijutsu no teichaku katei," *Kindai Nihon no keizai hatten*, ed. by K. Ohkawa and R. Minami (Tōyōkeizai, 1975).

⁸ A typical example of "too-late standardization" in Japan is the frequency of alternating current: 50 HZ in East Japan and 60 HZ in West Japan. The former was based mainly on imported technology from Europe, the latter mainly on technology from the U.S. They have not yet been integrated because the suitable timing was missed. Double standards still bring great inconvenience into our daily life even today.

⁹ The term technical standard may be defined as follows: A [technical] standard is a written formulation to serve during a certain period of time for defining, designating or specifying certain features of a unit of measurement, a physical object, a method, a capacity, a function or an arrangement. See John Gaillard, *Industrial Standardization: Its Principle and Application* (New York: H.W. Wilson Co., 1934), Chap. III. Technical standards are conventionally classified into three types: (1) basic standards (e.g. standards for technical terms, units, definition, etc.); (2) property standards (e.g. standards for products, parts and materials relating to quality, shape, size, function and content); and (3) method standards (e.g. standards for tests, inspections, operations, etc.).

energies to R&D activities. As the result of standardization, the shortening of delivery times, the saving of raw materials, the prevalence of fair and objective trades, etc. are also frequently observable.

On the other hand, standardization is also attended by some negative factors, such as the cost of establishing the standards themselves, the cost of switching specifications, the re-examining costs resulting from the appearance of new techniques and the disappearance of the individual firm's uniqueness. Still, it is broadly accepted that the benefits from standardization normally surpass its costs by about 10–18 times within a 5–10 year period.¹⁰ This is especially true in the case of national standards, since the externality effects of standardization on the macro level is much greater than that on the micro level. Finally, we should like to emphasize that: (1) the market expansion effect and the quality improvement effect are of greatest significance among all the above benefits of standardization from our viewpoint of macro-policies for appropriate technology; and (2) national standards provide greater benefits particularly to small and medium firms, i.e. non-first-class firms, which are often required reorganization of their production system, since national standards are usually fixed on the basis of the technological levels of large, first-class firms. On the premise of these general features of standardization, we now examine the role of national standards in the development of the Japanese machine-tool industry.

II. *Development and Technological Problems of the Machine-tool Industry in Wartime Japan*

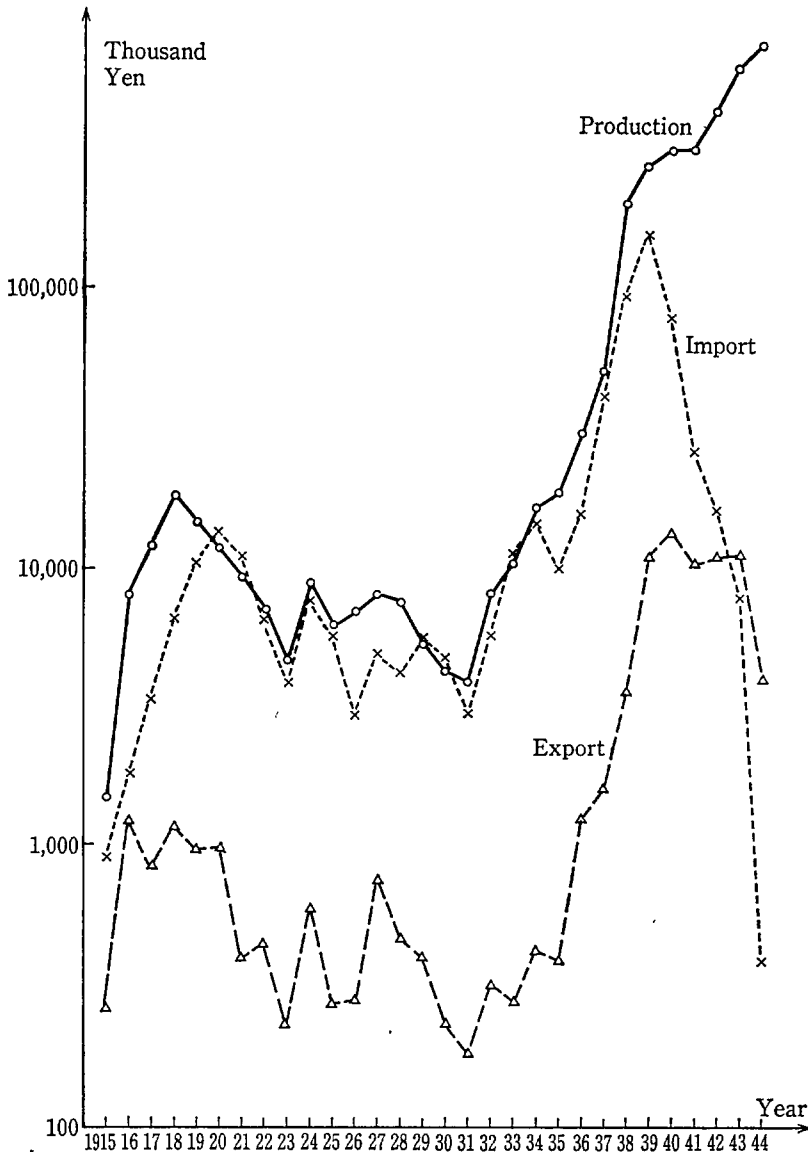
1. *The Rapid Expansion of Demand and Development Bottlenecks*

The Japanese machine-tool industry began to show signs of development during World War I, mainly because the supply to the Japanese market by foreign competitors experienced a relative decrease due to the war despite a rapid expansion of demand. However, as is shown in Fig. 3, the real development of the industry in earnest did not start until 1931, the year of the Manchurian Incident. This more active development was basically promoted by two demand-factors: (1) the demand for machine tools resulting from the rapid development of the heavy industries in the 1930's; and (2) the gradually expanding demand originated from the Fifteen-year War with China.

While these demands supported development of the machine-tool industry on the one hand, their overly rapid increase also immediately revealed serious limitations of the industry's development, limitations which are general features of the young machine-tool industry in late-industrializing countries. That is, first, most machine-tool factories were adopting the "diversified small-volume production" system. In other words, specialization of production among factories was not well-developed, and they produced various types of machine tools and nearly all the required parts by themselves, despite the generally

¹⁰ Benefits from interchangeability and interface-adaptability are considered the greatest among various benefits stemming from standardization. See, for instance, International Organization for Standardization (ed.), *Benefits of Standardization*, Geneva: ISO, 1982 [the translator's note in the Japanese version of this work is especially helpful; *Hyōjunka no ben'eki*, trans. S. Matsu'ura, Tokyo: Nihon-kikaku-kyōkai, 1983].

FIG. 3. JAPAN'S PRODUCTION, IMPORT AND EXPORT OF MACHINE TOOLS



Source: Nihon-kōsaku-kikai-kōgyōkai (ed.), *Kōsaku kikai kōgyō sengo hatten shi*, Vol. I (Kikai-shinkōkyōkai, 1984), pp. 34-35.

small workshops. This system was marginally workable when production to order was still dominant in the industry, but became inappropriate as the expanding demand necessitated mass production of machine tools of consistent quality.

Secondly, since most of Japan's machine-tool factories were equipped only with universal-type machines and the labor-boss system was prevalent, the shortage of skilled workers

became serious as the industry expanded rapidly in the 1930's. To solve the difficulty, the significance of single-purpose and special-purpose machine tools was stressed—particularly after the late 1930's—because these types of machine tools in principle require less skill than does the universal type.

Thirdly, the rate of dependence on imports for machine tools was persistently very high up to 1938 (nearly 50 percent in value terms, see Fig. 3).¹¹ Quality machines, in particular, had to be imported from advanced countries. The major exporters of such machine tools were the U.K. up to World War I, and the U.S. and Germany after the war. Although Japan could enjoy the respective advantages of the machine-tool industries of each of those countries, the importation from various countries, in fact, resulted in the transplanting of the complexity of different industrial standards under the respective technological system into the Japanese machine-tool industry. For instance, as the industry adopted both systems of the metric screw thread and the Whitworth (British inch) screw thread, the pitch of a lead screw in the lathe was diversified for threading either of them. Usually the change-gear system of the improved Japanese lathes was, therefore, complicated to produce both types of screws. The inconvenience of different gear-tooth profiles also originated from the co-existence of both module (metric) and diametral pitch (British inch) systems. Similarly, the varied sizes and shapes of taper keys, transmission gears, joints, fixtures, etc. all posed difficulties for the promotion of mass production.

Fourthly, the technological level of the Japanese machine-tool industry was still quite low in the 1930's, as compared with those of advanced Western countries. Even the products of first-class machine-tool makers were almost complete imitations of foreign machines. What is worse, the quality of those products was much inferior to that of the original machines. Generally speaking, the prices of first-rate domestic machine tools amounted to 70–80 percent of the (imported) prices of first-class foreign machines,¹² despite of the fact that the former's productivity was said to be only half of the latter's. That is to say, domestic machine tools were comparatively expensive considering their quality. On the other hand, there were many tiny second and third class workshops, which were producing simplified machine tools of inferior quality. Since both their quality and prices were extremely low, such workshops were not exposed to competition from foreign makers. At any rate, the improvement in the quality of machine tools of various classes was an urgent problem awaiting solution throughout the Japanese machine-tool industry as a whole.

2. *Development of the Machine-tool Industry Prior to the 1930's*

Before pinning down more precisely the technological level of Japanese machine tools of the 1930's, we should like to briefly sketch the historical development of Japan's machine-tool industry. The first machine-tool shop in Japan, Ikegai, independently produced two

¹¹ The exports from Japan shown in Fig. 3 consisted mainly of junior-type lathes, low-quality shapers, sawing machines, etc. These were usually exported to China and other Asian countries, but sometimes to Russia, the U.K., etc.

¹² See, for example, Yokosuka-kaigun-kōshō (ed.), *Yokosuka kaigun kōshō shi* [A history of Yokosuka Naval Arsenal], Vol. 4 (Tokyo: Hara-shobō, 1983 Reprint), and Toshiaki Chokki, *Nihon no kōsaku kikai kōgyō no hatten katei no bunseki* [An analysis of the development process of the Japanese machine-tool industry] (Tokyo: Published by the author, 1963), pp. 98–103.

hand-powered lathes on the model of a French lathe in 1889.¹³ Some other important workshops such as Niigata, Shibaura, Kisha and Wakayama were also established and had started to produce very primitive machine tools before the end of the nineteenth century. But the demand for such domestic machines was negligibly small, because their technological level was so low that government and other factories were unable to adopt them. Thus their main activities became the repairing and maintenance of other production machines, and the demand for machine tools was satisfied by imports from foreign countries.

This situation gradually changed after the Russo-Japanese War (1904–1905) for two reasons: Some heavy industries began to show symptoms of rapid development; And a part of the military demand was shifted from foreign to domestic machine tools in light of the war experience. In particular, the military realized the necessity of fostering the domestic machine-tool industry and itself contributed to the improvement of the quality of domestic machine tools through the strict inspection of military orders. Consequently, in 1905 based on its previous experience, Ikegai produced engine lathes on the first accuracy inspection against the U.S. Bradford standard.¹⁴ This policy was furthermore intensified in Ikegai's production after 1906 under the guidance of C.A. Francis, previously an engineer for the Pratt & Whitney Co. and then a lecturer at the Higher Technological School of Tokyo. Francis was the first to introduce some bases of mass production into the Japanese machine-tool industry, namely the ideas of quality control and standardization, and the use of jigs, fixtures, dial gauges, calipers, etc. On this basis the Ikegai Machine Co. was able to produce the highest-quality machine tools in the industry.

In 1909, the Karatsu Ironworks started the production of machine tools under the scientific management of T. Takeo, a competent engineer who had studied in a U.S. engineering college and had worked in New England for three years. Since Karatsu's products were also of high quality and could meet the military's requirements, the company was able to supply some large-sized machines such as a gun-barrel lathe, a crankshaft lathe and a vertical lathe to the military during the World War I—the first domestically produced machines of their kind. As is often pointed out, the World War in fact brought a boom to the Japanese machine-tool industry. Tiny machine shops mushroomed and produced low-quality machine tools as well as tools, although many of them were weeded out after the war. A few first-rate makers were even able to initiate the export of their products to European and Asian countries.

For instance, in 1913 Ikegai developed a unique all-gear lathe, the Ikegai B-type lathe, which it exported to the U.K. in 1915. Furthermore, Ikegai succeeded in the first mass production of (cannonball) lathes during the war, many of which were supplied to the mil-

¹³ Meiji Japan already had several government machine shops before 1889. And Kiheiji Itō is sometimes said to be the first person to have produced a treadle lathe (in 1875). See Yaekichi Sekiguchi, "Wagakoku kōsaku kikai hattatsu shi (2)" [A history of the machine-tool industry in Japan, Part 2] *Kōsaku kikai*, Vol. 1, No. 2 (May 1938). But we tentatively regard Ikegai as the first machine-tool workshop in the private sector.

¹⁴ The lathes were produced for the Higher Technological School of Tokyo. The specifications are available. See Charles A. Francis, "Specification of 14 Inch Lathe for the Higher Technological School of Tokyo," *Nihon kikai gakkai shi*, Vol. 9, No. 16 (Nov. 1906). See also the article by the same author under the same title in Vol. 8, No. 13 (July 1905) of *Nihon kikai gakkai shi*.

itary and exported to Russia.¹⁵ Wakayama also exported their lathes to Russia, while Kisha exported to India and Ohkuma exported both lathes and shapers to China in this period. Several new developments experienced in the World War I period, then, are worthy of note in the context of the history of the machine-tool industry: (1) The wartime boom invited many new entries, and this was to some extent helpful in promoting market competition and specialization in the industry; (2) The quality requirements of the military greatly contributed to improving the technological level of Japanese machine tools, particularly through the orders for large-sized, military-purpose machine tools placed with first-rate domestic makers; And (3) some advanced workshops, against the background of rapidly expanding demand, realized the mass-production of standardized machines outgrowing the previous stage of sketch production to order.

On the other hand, the mushrooming of machine shops in the boom period inevitably led to overproduction in the tranquil period after the end of the war. Machine tools, as "mother machines," are always subject to an amplified influence of the business cycle. In the case at hand, the impact of the Washington Disarmament Conference of 1921 on military demand was serious, and it plunged the machine-tool industry into a long recession in subsequent years. The year 1921 was an epochal one in other senses as well: (1) The Japanese Engineering Standard (JES) was initiated from this year. As will be confirmed in the next section, standardization was an indispensable condition for the effective expansion of market size and for upgrading the overall technological level of the industry; And (2) the [First National] Machine-tool Exhibition was held in the same year in Osaka. The exhibition is considered to have given the industry as a whole great incentives by providing and diffusing the most advanced technological information to even the smaller workshops.

But Table 2 reveals the real level of Japanese machine-tool technology at that time. That is to say, although remarkable progress had been realized during World War I, the essence of Japanese technology even at its best remained the copying of first-rate foreign machines. And to copy them perfectly was still beyond the capabilities of the Japanese machine-tool industry of those days. Even the best quality Japanese machine tools were, therefore, much inferior to imported ones. The consensus view was that, what was worse, Japanese machine tools were comparatively expensive for their quality.¹⁶

These general drawbacks aside, there existed some noteworthy exhibits at the 1921 exhibition. For instance, the Ikegai G-type lathe, which took first prize, embodied various newly patented devices such as the automatic threading system, the polished cast-iron bearing and the lever operated feed-gear change system.¹⁷ A tool-room lathe by Karatsu and

¹⁵ The Ikegai B-type lathe included the patented Norton-type change-gear system for threading both metric and Whitworth screws. The gears were produced by Gleason's bevel gear cutting machines by the generating method. The turret lathe was first designed in 1919, and cannonball lathes were produced at a rate of about 50 machines a month. The limit gauge system was also adopted in this period.

¹⁶ A detailed report of this Exhibition is available. See Korekazu Hirasa (ed.), *Nōshōmu-shō shusai kōsaku kikai tenrankai hōkoku* [Report on the machine-tool exhibition sponsored by the Ministry of Agriculture and Commerce], Osaka: Kōsaku-kikai-tenrankai-kyōsankai, 1922. Precious information on comparisons between domestic and foreign machine tools of those days is provided in the appendix of the famous survey: Kuramae-kōgyōkai kōgyō-chōsakai, *Kikai kōgyō-bu chōsa hōkoku-sho* [Report on a survey conducted by the machinery department], Tokyo: Kuramae-kōgyōkai, 1926.

¹⁷ For the technological development of the Ikegai Machine Co., the book by former president Hayasaka is quite helpful. See Tsutomu Hayasaka, *Hayasaka Tsutomu zenshū: Kōsaku kikai to bunmei* [Collected works of T. Hayasaka: Machine-tools and civilization], ed. by special committee, Tokyo: Komine-kōgyō-gijutsu, 1964.

TABLE 2. ENTRIES IN THE JAPAN'S MACHINE-TOOL EXHIBITION HELD IN 1921 AND 1940

Year	Class of Machine Tool	Applicants [A]	Acceptances [B]	Ratio [B/A]	Comments of Exhibition Examiners
1921 [A. 109 B. 60]	1. Lathes	40	28	0.70	Some self-designed. Little interchangeability. Insufficient use of jigs.
	2. Milling Machines	13	9	0.69	Mostly imitations of foreign makers.
	3. Drilling Machines	13	3	0.23	Majority, imitations. Insufficient use of jigs.
	4. Horizontal Boring Machines	3	2	0.67	Majority, imitations. Insufficient use of jigs.
	5. Shapers	5	3	0.60	Imitations. Little interchangeability. Poor casting.
	6. Gear Cutters	2	1	0.50	Design similar to foreign makers.
	7. Grinders	11	5	0.46	Mostly imitations.
	8. Planers	5	3	0.60	Imitations. Little interchangeability. Poor casting. Low quality.
	9. Others	17	6	0.35	Some tools satisfactory. A little progress in roller bearings.
1940 [A. 281 B. 115]	1. Lathes	122	45	0.37	Accuracy not bad. Some self-designed.
	2. Milling Machines	44	17	0.39	Many imitations. Many of roller bearing type.
	3. Boring Machines	30	8	0.27	Mostly imitations of foreign makers.
	4. Horizontal Boring Machines	7	3	0.43	Mostly imitations of foreign makers.
	5. Shapers	11	3	0.27	Many imitations.
	6. Gear Cutters	7	6	0.86	Many imitations.
	7. Grinders	42	23	0.55	Mostly imitations. Insufficient accuracy. A little progress.
	8. Others	18	10	0.56	

Sources: 1) For the 1921 Exhibition, Nihon-kikai-gakkai (ed.), *Nihon kikai kōgyō 50-nen shi* (Nihon-kikai-gakkai, 1949), p. 504, and K. Hirasu (ed.), *Nōshōmu-shō shusai kōsaku kikai tenrankai hōkoku* (Kosaku-kikai-tenrankai-kyōsankai, 1922), pp. 66-71.

2) For the 1940 Exhibition, Kōsaku kikai nikansuru shiryō, Vol. 5, No. 4 (Apr. 1942), p. 4, and Shōkōshō-kikaiyoku, *Shōkōshō shusai kōsaku kikai kōgyō shinkō tenrankai hōkokusho* (Shōkōshō, 1940).

a turret lathe by Niigata were also highly estimated, and the general accomplishment level of milling machines was rather high, although most of them were copied from foreign machines. All machines at the exhibition were closely examined with the use of measuring instruments (limit gauges, dial gauges, micrometers, etc.). This inspection produced an unexpected by-product. Since accuracy inspection standards had not yet been established for Japanese machine tools, the National Iron Workers Association asked the Society of Mechanical Engineers to establish such standards.

As has already been mentioned, the machine-tool industry went through a long recession after the exhibition partly owing to a general scaling down of military demand under the international disarmament program. The major demand for machine tools in the 1920's, such as it was, was derived from the machinery industry, particularly the textile machinery and railroad machinery industries, which meant that the production of special-purpose machine tools became the main stays of first-rate machine-tool companies during this recession period.

The Ministry of Railways tried to promote import substitution of mother machines especially after the war. As a result, not a few domestic special purpose machine tools such as the car-wheel lathe, driving-wheel lathe and axle lathe, came to be supplied by Kisha, Gasuden and other firms to replace most of the equivalent foreign machines by the end of the 1920's. With the textile machinery industry also developed rapidly in the same decade, orders for many special machines were placed with the machine-tool industry so that spinning and weaving machines might be manufactured for both the Japanese and Chinese textile industries. Ikegai, Ohkuma and other workshops supplied special purpose-type drilling, milling and grinding machines for use in making carding engines, spindles, tin rollers, etc.¹⁸

Some other new products of a universal type were also developed in the 1920's. The profile shaper, the multiple-spindle drilling machine, the large-sized hobbing machine, the internal grinder and the roll grinder are typical examples of such products first provided by domestic makers during the period. Despite the long recession in the industry, then, the variety range of domestically-made machine tools widened steadily in the 1920's. It must, however, be borne in mind that the demand for them was mainly supported in this decade by non-military demand generated within the private sector.

3. *The Technological Level of Japanese Machine Tools in the 1930's*

The demand for machine tools re-expanded rapidly after 1931 as the result of the development of both military and non-military industries. That is, (1) the heavy industries such as the automobile, aircraft, ship-building, railroad and textile machinery industries began to develop steadily after the recovery from the Great Depression; and (2) Japan's armed intervention in China was intensified after the Manchurian Incident, thereby inducing an expansion of the military industry. We have already pointed out four difficulties which the Japanese machine-tool industry had to confront with this rapid expansion of demand in the 1930's (see pp. 131-33 above). Since the years 1939-40 can be considered as a kind of technological turning point from the viewpoint of the quality development of Japanese machine tools, it may be worthwhile to confirm the technological level prior to the new stage against the historical development so far described. In particular, we should like to judge their quality in comparison with foreign-made machine tools.

The quality of the machine tool, we define, consists of four elements: (1) accuracy; (2) productivity or efficiency; (3) durability; and (4) functionality. The last element functionality includes structural stability, ease of handling and repair, economy in operation and so forth. Each of the four elements is indispensable for defining quality, and they are all closely related to one another. As for machine tool accuracy, the desired level has to be fixed by industrial standards according to the technological level of the industry. In Japan, this was realized in the form of JSME (the Japan Society of Mechanical Engineers) standards after 1926. That is to say, the accuracy inspection standard for an engine lathe was set up by the Society in 1926; the accuracy standards for upright and radial drilling machines

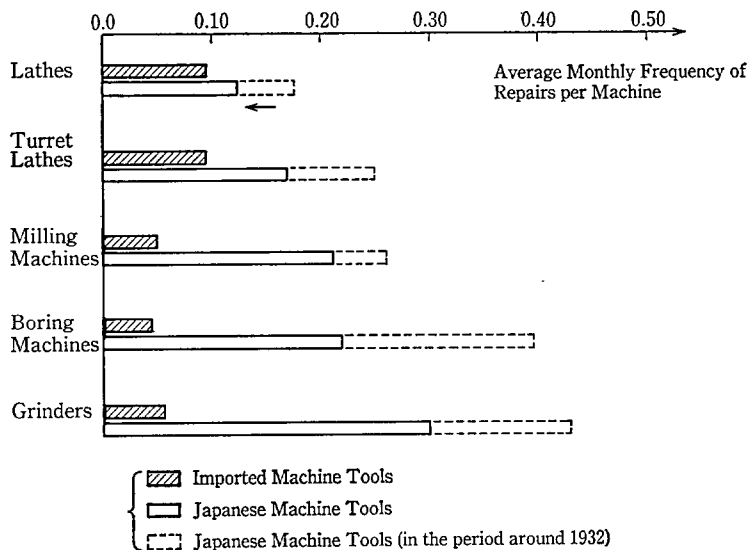
¹⁸ For further detailed information on special purpose machine tools, see Nihon-kikai-gakkai, *Nihon kikai kōgyō 50-nen shi* [A 50-year history of the Japanese machinery industry] (Tokyo: Nihon-kikai-gakkai, 1949), pp. 529-538.

were established in 1929; and the accuracy standards for horizontal and vertical milling machines were fixed in 1931.

Although these standards were more liberal in the tolerance than Schlesinger's standards which were established a few years later in Germany, they were epoch-making in the sense that Japanese machine tools were provided with their first accuracy targets for attaining a certain level of quality.¹⁹ The JSME standards, fixed by a committee consisting of academics and chief engineers of representative machine-tool makers, were double standards in order that even smaller workshops might have a lower accuracy level to aim at. Nevertheless, it is well known that only a limited number of products of first-class makers could meet even those accuracy standards.²⁰

While it is true that accuracy is a most crucial element in the quality of machine tools, if the need for durability is not fully satisfied, even high levels of accuracy become meaningless. Figs. 4 and 5 demonstrate that Japanese machine tools were lacking in durability or sturdiness, as compared with foreign machines in the 1930's. But Fig. 4 also indicates that in the second half of the decade mechanical troubles were greatly ameliorated relative to the first half, although the frequency of such troubles was still very high. It comes as

FIG. 4. REPAIR FREQUENCY OF IMPORTED AND DOMESTIC MACHINE TOOLS
(around 1938).



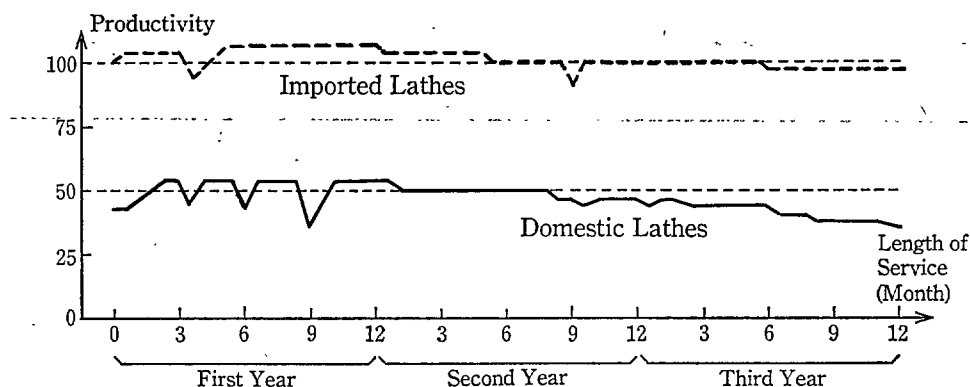
Note: This record was compiled by the Nakajima Aircraft Co.

Source: M. Naruse, *Nihon gijutsu no botai* (Kikaiseisaku-shiryō-sha, 1945), p. 52 [adapted].

¹⁹ See Taketaro Matsuda, "Kōsaku kikai no kensa-kikaku ni tsuite" [On inspection standard for machine tools], *Nihon kikai gakkai shi*, Vol. 44, No. 286 (Jan. 1941), and Yaekichi Sekiguchi, "Wagakoku kōsaku kikai hattatsu shi (11)" [A history of the machine-tool industry in Japan, Part 11], *Kōsaku kikai*, Vol. 2, No. 3 (Mar. 1939).

²⁰ The result of a cutting accuracy test, viz. a part of the dynamic inspection, conducted by the Japan Optical Co. is available. See Hiroshi Shirahama, "Ippan kōsaku kikai no kōsaku-seido" [The cutting accuracy of ordinary machine tools], *Kōsaku kikai*, Vol. 1, No. 4 (July 1938).

FIG. 5. DURABILITY OF IMPORTED AND DOMESTIC LATHES



Note: This comparison was made at the Nakajima Aircraft Co. around 1937-39.

Source: M. Naruse, *Nihon gijutsu no botai* (Kikaiseisaku-shiryō-sha, 1945), p. 52.

somewhat of a surprise that the productivity of Japanese lathes was as low as is suggested by Fig. 5, despite the fact that it is first-rate domestic machines being examined. As for functionality, it was considered to be almost satisfactory with the exception of some minor points, since various local adaptations were usually embodied in imitative domestic machine tools.

To be brief, the quality of Japanese machine tools in the 1930's was still much inferior to first-rate foreign machine tools in terms of accuracy, productivity and durability. In particular, machine-tool makers themselves had to rely heavily on foreign machine tools as fine-quality mother machines, because the copying principle is at work in its purest form in the case of machine-tool production (see Table 3). The same deficiencies are confirmed in the results of a questionnaire survey conducted by the Japan Society for the Promotion of Science in 1939.²¹ This survey is more specific in pointing out the problems of Japanese machine tools. For instance, it says the inaccuracy of domestic machine tools was frequently generated by: (1) the divergent accuracies of different component parts; (2) great friction and wear stemming from insufficient seasoning and heat-treatment; and (3) unsatisfactory bearings or gears. Similarly, poor durability is usually attributed to troubles with clutches or brakes (stemming from inappropriate heat-treatment and poor materials), and also troubles with gears or lead screws (stemming from inaccurate shapes and pitches). Functionality was not fully satisfactory either, since Japanese designs on inadequate imitations often resulted in: (1) inconvenience in repair or disassembly; (2) poor circulation of lubricating oil; and (3) operational awkwardness of handles and levers. Each of these difficulties contributed to the low productivity of Japanese machine tools. Furthermore, poor stiffness and balancing in domestic machines were also said to lead to low productivity, because they made machine tools unsuitable for high-speed cutting.

For all these reasons, high-grade machine tools still had to be imported from foreign

²¹ See Takeo Shida, "Kishubetsu ni mita gaikoku izon nitsuite" [Dependence on foreign machines of various classes], *Kōsaku kikai nikansuru shiryō*, Vol. 3, No. 11 (Nov. 1940). This survey covers 80 makers and users of machine tools in both the private and public sectors.

TABLE 3. PROPORTION OF IMPORTED MACHINE TOOLS IN SELECTED MAJOR MACHINE-TOOL COMPANIES (1939)

Company	No. of Domestic-made Machines	No. of Imported Machines	Proportion of Imported Machines	Main Items [in terms of value]
Shinohara	593	72	10.8	Milling Machines (62%), Lathes (36%)
Hitachi	495	94	16.0	Milling Machines (75%), Lathes (19%)
Ikegai	380	205	35.0	Lathes (58%), Horizontal Boring Machines (22%)
Kokusan-seiki	74	411	84.7	Lathes (98%)
Ohkuma	380	56	12.7	Lathes (62%), Milling Machines (17%)
Shibaura	230	79	25.6	Lathes (72%)
Mitsubishi-denki	168	90	34.6	Boring Machines (56%), Lathes (44%)
Tōyō-kikai	78	170	68.5	Lathes (100%)
Dainihon-heiki	53	156	74.6	Grinders (99%)

Note: The data on main items are for 1941 in the cases of the Shibaura and Dainihon-heiki Cos.

Source: Nihon-kōsaku-kikai-kōgyōkai, *Kōsaku kikai kōgyō sengo hatten shi*, Vol. I (Kikai-shinkō-kyōkai, 1984), pp. 75, 56–57 [adapted].

countries. This was particularly true for the jig boring machine, the gear cutting machine, the gear grinder and the thread grinder. Conversely speaking, promotion of the production of such quality machines and improvement of the quality of universal-type machines were urgent tasks awaiting solution in the 1940's by the Japanese machine-tool industry, for even major workshops were still mainly producing such universal machine tools as lathes and milling machines at the end of the 1930's, as is shown in Table 3.

On the other hand, already in the 1930's it is possible to find some early signs of development along the line just suggested. In 1935 Ikegai completed a new standard lathe, its D-type, on the model of the famous German VDF (Vereinigte Drehbank Fabriken) lathe. That lathe became very popular and was mass-produced, since it newly embodied the alloy-steel gear, the ball-and-roller bearing and the spline shaft, all elements which were indispensable for realizing higher efficiency. In the same year, Ikegai also developed a high speed precision lathe (its H-type) which was the first lathe in Japan to adopt the cemented carbide tool.²² Around 1938, Tōyō Kikai also adopted the mass-production system for their lathes (the Kōhan; 150 units a month) modelled after the Lodge-Shipley. In addition, Karatsu developed the bevel-gear cutting machine in 1934 and Okamoto first succeeded in perfecting the gear generating machine in 1935.

Although all of these evidences bespeak an advance in the technological level of the Japanese machine-tool industry, two reservations are in order. First, while it cannot be denied that Japanese machine tools realized adequate technological progress in the 1930's,

²² In 1926 the first cemented carbide bit for super high speed cutting, the Widia, was commercialized in Germany. In Japan similar cemented carbide tips, (e.g. Tungalloy, Igetalloy) were developed in the 1930's. Ohkuma's OHW-type lathe was also equipped with this cemented carbide cutting tool. It was often said that only Ikegai's H-type lathe was sufficiently accurate for the precise requirements of the automobile industry.

the essence was still the copying of foreign machines—even in the case of first-rate machine-tool makers. The exhibits at the Machine-tool Industry Promotion Exhibition held in 1940 support our contention (see Table 2). What progress there was, was nothing but the progress of imitative ability. Still, we are bound to consider this imitative development of technology, not as a negative factor, but as a very important transitional phase necessary in the process of technological development.²³

Secondly, there is no doubt that the technological level of the average machine shop was fairly low, even though major machine-tool companies had already attained a certain level of technology. Statistical data show that the number of machine-tool workshops increased rapidly after 1933, and that in 1939 there were nearly 2,000 workshops, seventeen of these were major (authorized) companies with more than 200 machines, 386 were medium-sized machine shops with more than twenty machines, while the rest were tiny workshops.²⁴ Table 4 is suggestive of the technological level of the second string medium-sized machine shops. (1) The composition of installed machines bespeaks a production by low-level technology most typically using primitive universal machine tools such as lathes and drilling machines; And (2) the quality level of the majority of the machines implies that

TABLE 4. INSTALLED MACHINE TOOLS IN THE MACHINE-TOOL INDUSTRY

(1940; 436 medium-sized machine shops)

Class of Machine	Number	Proportion of Total Machines	Proportions of Different Qualities
1. Lathes	14,990	44.6%	A (14.0%), B (18.0%), C & Below (68.0%)
2. Drilling Machines	3,633	10.8	A (12.0%), B (18.0%), C & Below (70.0%)
3. Horizontal Boring Machines	645	1.9	
4. Milling Machines	2,460	7.3	A (14.0%), B (29.0%), C & Below (57.0%)
5. Grinders	6,592	19.6	A (21.0%), B (22.0%), C & Below (57.0%)
6. Gear Cutters	703	2.1	
7. Planers	1,292	3.8	
8. Shapers	1,681	5.0	
9. Slotters	576	1.7	
10. Broaching Machines	28	0.1	A (46.0%), B (14.0%), C & Below (40.0%)
11. Others	1,040	3.1	
Total	33,640	100.0	

Notes: 1) Figures cover all machine-tool workshops with more than 20 machines, except for 21 authorized companies.

2) Information on the quality of installed machines is for the year 1941.

Source: Osaka-furitsu-shōkō-keizai-kenkyūjo (ed.), *Nihon kōsaku-kikai kōgyō no hatten to sono genjō* (1957), pp. 43, 50.

²³ Japan's imitation was already notorious in those days. Up until now imitation has been regarded as a definite negative factor for future technological development. See, for instance, John Orchard, *Japan's Economic Position: The Progress of Industrialization* (New York: Whittlesey House, 1930), pp. 252–54.

²⁴ In general the information on tiny machine shops is extremely poor except for *Zenkoku kōjō tsūran* [Directory of domestic factories], ed. by the Ministry of Commerce. According to them (for the years 1932, 1937 and 1938), the numbers of parts makers and tools makers hardly increased in this period, despite the very rapid expansion of tiny all-round workshops. Most of the latter produced other primitive machines in addition to machine tools, and extensively engaged in repairing as well.

shops with such inaccurate mother machines could not avoid producing low-quality products.

The above discussion of the technological level of Japanese machine tools ultimately boils down to three problems urgently awaiting solution. The quality of Japanese machine tools was still considerably low. The first necessity, therefore, was to improve the accuracy and durability of the machines by adopting new technological progress developed in the 1920's and 1930's in Western advanced countries. And, since in those days almost all machine tools produced in Japan were copied from foreign machines and, what was worse, the industry could not even yet perfectly imitate sophisticated machines of high quality, the production of new quality machines based on domestic R&D activities was the second necessity. Finally, since although the machine-tool production market rapidly expanded in the 1930's due to a suddenly increased demand, most new firms entering the market were tiny all-round or *de facto* repair shops, the third necessity was to promote their specialization and competition through the development of product-interchangeability. Standardization of machine tools by the adoption of national standards was, we consider, the most effective and indispensable means for simultaneously solving the three problems.

III. *The Advancement of Technological Levels and Standardization of Machine Tools*

1. *Reorganization of the Production System*

After the China Incident (1937), the Fifteen-year War was intensified by Japan's full-scale invasion of China. Although the Japanese machine-tool industry was developing rapidly in those days as the heavy industries were steadily expanded, the government strongly felt that neither the growth rate nor the foundation of the Japanese machine-tool industry was yet sufficient to support continuation of the war. Thus, in 1938 the government enacted the *Kōsaku-kikai Seizō-jigyō Hō* [Special Law on Machine-tool Manufacturers], in particular to foster large, first-rate machine-tool makers by granting various special tax exemptions and subsidies.²⁵ As the National Mobilization Law was enforced in the same year, other laws relating to machine-tool production were also legislated under the wartime planned economy.

The same year the Ordinance on Machine-tool Supply and the Grants Ordinance on Subsidies for Trial Manufacture were implemented. The former aimed at giving priority in machine-tool supply to the military demand, and the latter at encouraging the research and development of new quality machines. But actual results fell short of the government's expectations owing to a continuous expansion of the demand for machine tools. In the next year, therefore, economic control by the government was further strengthened and the two Ordinances were revised into the Ordinance on Machinery and Equipment and the Ordinance on Experimental Research, respectively. The ordinance for controlling

²⁵ Machine-tool makers with more than 200 machines were authorized to enjoy the privileges. The Special Law on Aircraft Manufacturers was enacted simultaneously. It is to be noted that this law included a compulsory obligation for suppliers to meet designated standards.

machinery and equipment, which restricted also market entry by small machine shops, proved quite effective as it was executed along with distribution controls on iron and steel.

What should be borne in mind here is that these legislative protections were all aimed at the development of first-class machine-tool makers alone. For the first and second problems mentioned above (p. 142) could be overcome relatively easily by the authorized large makers under the protective institutions. On the other hand, the overall development of the machine-tool industry, and particularly small- and medium-sized workshops, was of equally great significance in order to promote the production of quality parts and tools through specialization, viz. to overcome the first and third problems. For realization of this aim, however, a standardization policy alone was applied to such workshops without the provision of any special favors. We nevertheless consider that the standardization policy ultimately produced huge effects, although they were only implicitly discernible.

The pace of setting up the Japanese Engineering Standards was rather slow, in the eighteen years up to 1938 a mere 455 JES's being established. This casual pace caused serious inconveniences for the mass production of machine-tools, particularly military-related machines, since they normally had to satisfy some quality requirements and attain a certain degree of interchangeability. In 1938, therefore, the government decided to establish a new system of Temporary Japanese Engineering Standards (denoted by JES(T) hereafter), which had two features: (1) simplified procedures for fixing standards and swiftly announcing them; and (2) inclusion of less strict standards for various substitutes from the viewpoint of the needs of the wartime economy. The numbers of JES(T) increased after 1939, and about half of them can be considered as machinery-related standards in the broad sense.

Simplification of products (types, forms or designs) is an important part of standardization. The mushrooming of small- and medium-sized workshops in the machine-tool industry in the 1930's resulted in the production of nearly 1,000 more-or-less similar varieties of domestic lathes around 1938. Hence, simplification or standardization of machine types was unavoidable for the advancement of interchangeability. This was the main reasoning behind the government's publication of the blueprints of the so-called "S-model" machine tools, jointly designed by the Big Five makers in 1938, which was chiefly for the benefit of small- and medium-sized machine shops. In other words, the government adopted a double-sided policy under the National Mobilization Law, namely the promotion of R&D activities among the large, first-rate makers and of standardization among the small- and medium-sized workshops.

Although around 1938 was the days of mass production of inferior articles in the machine-tool industry as the result of the mushrooming phenomenon, the industry did attain a technological turning point in 1939-40. That is to say, a distinct upgrading in the quality of Japanese machine tools is observable after 1940. This upgrading can be considered both as the fruit of the above-mentioned policies, which were strengthened greatly from 1941, and as the response to an emergency, i.e., the embargo on the export of machine tools to Japan by the U.S. in 1940. Next, we should like to confirm the effects of the government's double-barrelled policy.

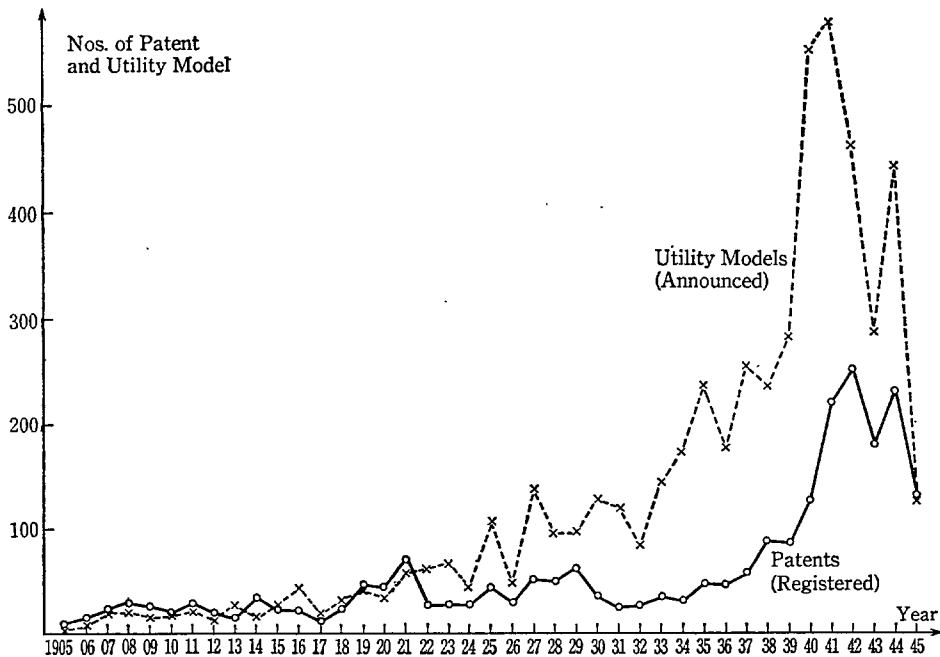
2. *The Research and Development of High-grade Machine Tools*

So far we have confirmed that, up until the late 1930's, the quality of Japanese machine

tools was quite poor, that the essence of machine-tool production was the imitation of foreign machines, and that the industry was technologically incapable of producing some high-grade machine tools. These implicitly supported by the data on patents and utility models. Fig. 6 shows that patenting activity was persistently stagnant up to around 1939, although utility model applications were already gradually increasing.²⁶ The fact that the numbers of patent and utility model applications and acceptances for machine tools were extremely small for many years implies the underdevelopment of the Japanese machine-tool technology.

Among the machinery industries, the quantity and quality of the patents (including utility models) granted for machine tools lagged far behind, as compared with, say, those for textile machinery. Machine tool patents accounted for only a few percent (in terms of applications) of all patents for the whole machinery industry in the 1930's. Furthermore, examination of the content of machine-tool-related patents reveals that nearly half of them were unsophisticated claims relating to ordinary engine lathes, their parts and primitive

FIG. 6. DEVELOPMENT OF PATENTS AND UTILITY MODELS FOR MACHINE TOOLS



Note: Figures cover classification code No. 74 of patents and utility models.

Source: Tokkyo-chō (ed.), *Tokkyo bunruibetsu sōmokuroku*, Gihōdō, 1958.

²⁶ For the conceptual differences between patents and utility models, their historical development and legislative revisions, see the concise summary in Tokkyo-chō [Patent Office] (ed.), *Tokkyo seido 70-nen shi* [Seventy years of the patent system] (Tokyo, 1965). For the features of Japanese patent activities, see Y. Kiyokawa, "Entrepreneurship and Innovations in Japan: Implications of the Experience of Technological Development in the Textile Industry," *Developing Economies*, Vol. 22, No. 3 (Sept. 1984).

grinders.²⁷ It is difficult for us to find any very unique ideas or sophisticated devices among the machine-tool-related patents of those days.

It is also bespoken by the fact that in the pre-war period no one in the machine-tool field was awarded the Blue Ribbon Medal, the most glorious decoration for inventors or technological innovators. Especially in the earlier period, many of the important patents related to machine tools were registered by foreigners, although the proportion of Japanese applicants increased gradually after World War I. Similarly, we cannot find any innovation relating to machine tools in the reliable lists of historically important inventions or technological innovations in Japan (lists such as those edited by the Patent Office, the Imperial Invention Association, etc.).²⁸ All of these pieces of evidence bear witness to the lack of originality or the imitative property in Japanese machine-tool technology. In the 1930's the understanding was almost unanimous that the Japanese machine-tool industry still lagged several decades behind the machine-tool industries of Western advanced countries technologically.²⁹

The government began earnestly to tackle this problem after 1938. The first policy adopted to hasten reduction of the gap was the subsidization of first-class machinery makers for R&D activities on high-grade machine tools. During the years 1938-42, sixty-two research projects were supported under the Grants Ordinance to develop quality machine tools, such as multi-spindle automatic lathes, precision horizontal boring machines, crank-shaft grinders, internal grinders and so forth. But since this subsidization policy was based on voluntary applications by the makers themselves, the demand for specific quality machine tools often went unsatisfied. To remedy this defect, the government strengthened the ordinance into the Experimental Research Ordinance under the National Mobilization Law in 1939.

The new ordinance in fact had a semi-compulsory nature strongly influenced by the military demand for the development of new, high-grade machine tools. In any case, under these promotional policies, the numbers of registered machine-tool-related patents and utility models rapidly increased after 1939-40, i.e. the technological turning point, although they were soon damped down again owing to the intensification of the war. Yet the important thing to note about the Experimental Research Ordinance is the fundamental policy that the goal in producing new quality machines was in principle to learn to copy completely the foreign machines. This was a reflection of the prevailing view of those days that the perfect copy was much superior to self-design.

More than 200 development projects of large makers were aided by the government grants, and seventy-eight of them had borne fruit by mid-1945. The significance of some

²⁷ The content of each patent may be confirmed from Tokkyo-chō (ed.), *Tokkyo bunruibetsu sōmokuroku* [Classified list of patents] (Tokyo: Gihōdō, 1958), and Tokkyo-chō (ed.), *Jitsuyō shin'an bunruibetsu sōmoku-roku* [Classified list of utility models] (Tokyo: Gihōdō, 1958).

²⁸ For instance, see the appendix tables on great Japanese inventions in Tokkyo-chō, *70-nen shi* and Kentarō Matsubara (ed.) *Nihon hatsumeika 50-ketsu-sen* [Fifty great inventors in Japan] (Tokyo: Hatsumei-toshokankōkai, 1952). For registrations by foreigners, see Kuramae-kōgyōkai kōgyō-chōsakai, *Chōsa hōkoku-sho*.

²⁹ See, for example, Kenji Motohashi, "Tokkyo o tsūjite mitaru saikin kōsaku kikai no dōkō" [The recent trend in machine tools as seen through patents], *Kōsaku kikai nikansuru shiryō*, Vol. 3, No. 1 (Jan. 1940), and "Zadankai: Kōkūki no taryō-seisan to kokusan kōsaku kikai" [Symposium: Mass production of aircraft and domestic machine tools], *Kōsaku kikai*, Vol. 4, No. 2 (Jan. 1941).

of the newly produced high-grade machine tools (e.g. the relieving lathe, the ball-bearing internal grinder, the thread grinder, the jig boring machine, the bevel gear cutting machine, etc.) was particularly great. Such machine tools were subjected to strict inspection at the National Machinery Experimental Station (in operating from 1941) after the enforcement of the Ordinance, and 70 percent of them were assessed as being of almost equivalent quality to foreign first-rate machine tools. The other 30 percent, though of slightly inferior quality, posed no problems for practical use.³⁰

Despite this high evaluation, it must be kept in mind that even perfectly copied machines are in general less efficient by at least 10 percent than the original models, although new devices are often developed in the process of imitation. Still, no one may deny that the research and development activities, which were strongly promoted by the government particularly to produce high-grade machine tools, contributed greatly to upgrading the technological levels of the large machine-tool makers. This was partly and indirectly due to standardization of machine tools in two senses: (1) the evolution of standardization in the industry provided large makers with the reserves necessary to concentrate on designing and developing; and (2) the advancement of the technological levels among large makers cannot be separated from that of small- and medium-sized machine shops, and linkage was mainly realized through the evolution of standardization. In other words one may maintain that, when an industry is still at the stage of imitation, standardization is more significant than research and development—particularly for upgrading the technological levels of the industry as a whole.

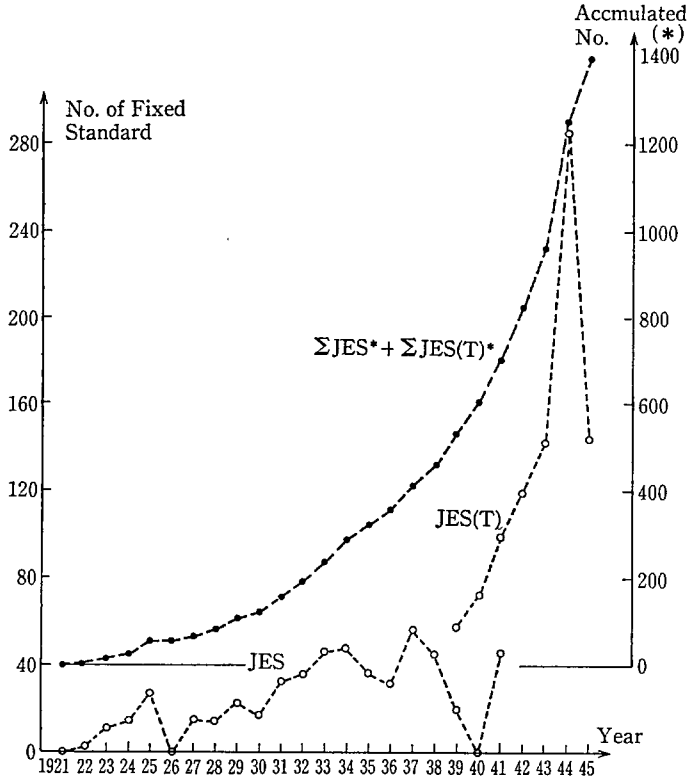
3. *Evolution of Standardization*

As is shown in Fig. 7, the numbers of Japanese Engineering Standards increased drastically from 1939 under the renovated system. These increases in JES and JES(T) can be considered as important indicator of quality improvement and of the degrees of interchangeability and specialization in the machine-tool industry. This is particularly so in the case of machine tools, since machine tools are most sensitive to the establishment of different standards, and are directly or indirectly connected with more than half of all industrial standards. That is to say, the standards for machine elements (viz. screws, bearings, gears, keys, etc.) are most universally applicable to various machines, including machine tools themselves; moreover the standards for metallic materials, electric parts and even machine oil are also related to the function and structure of machine tools. Thus, we may judge the quality improvement of Japanese machine tools and the evolution of specialization in the machine-tool industry from the accumulated number and content of fixed standards.

Although the establishment of the national standard system in Japan was not particularly late as compared with Western advanced countries (see Table 1), the pace at which standards were fixed was not so rapid in proportion to the degree of development of the Japanese manufacturing industry. Over a period of twenty years (1922–41), the JES Inquiry Board set up only 520 national standards. This was a major reason for the establishment of the JES(T) system under the wartime economy (see p. 143). In the seven years 1939–45, 931

³⁰ See Nihon-kōsaku-kikai-kōgyō-kai (ed.), *Nihon no kōsaku-kikai kōgyō hattatsu no katei* [Historical development of the machine-tool industry in Japan] (Tokyo: Kikai-kōgyō shinkō-kyōkai, 1962), p. 142. Chap. 7 of this book in particular contains quite precious information and data for our discussion.

FIG. 7. DEVELOPMENT OF JAPANESE STANDARDS



Source: M. Nakamoto (ed.), *JIS-JES kikaku sōmokuroku*, Nihon-kikaku-kyōkai, 1951 [JES(T) also included].

JES(T)'s were set up.³¹ Also, 660 Japanese Aircraft Standards were set up on an emergency basis from 1941 to 1945. This rapid growth in national standards indicated the deepening of specialization and advancement of technological levels in the industry.

Through examining the content of those standards more specifically, we may gauge the progress of interchangeability and quality improvement in machine tools. Under the JES system, the highest priority in the fixing of machine-tool-related standards was given to the most fundamental standards for the machinery in general, namely standards for machine elements and common parts. For instance, the standards for the metric (JES No. 13) and Whitworth (No. 68) screws were set up in 1924 and 1927 respectively; the standards for the Morse taper shank & socket (No. 35), keys (No. 71), involute tooth profiles (No. 327), T-slots (No. 361) and centers (No. 362) were successively set up in subsequent years.

After switching to the JES(T) system, more sophisticated standards for machine elements, jigs and fixtures, etc. were successively established (see Table 8 in Part II). In any

³¹ These figures do not include the numbers of revised standards, which were 154 for JES and 61 (our confirmation) for JES(T). The Precision Machine Control Association [Seimitsu kikai tōsei-kai; established in 1942] started to fix its own provisional standards from 1943. In 1944 the government also planned to set up special wartime standards. Neither plan had time to make a substantial contribution.

case, the following general features of machine-tool-related standards can be pointed out: (1) Accuracy inspection standards for machine tools, stricter than those of the previous JSME's, were fixed first as national standards in the JES(T) system³²; (2) Various standards for materials used in fabricating machine tools, e.g. high-speed steel (JES(T) No. 1), special tool steel (Nos. 2–5, 93–96) and cemented carbide (No. 831), were newly included; (3) Detailed standards for measurement instruments, e.g. limit gauges (Nos. 287, 442, 632, 659, 798–99, 884), block gauges (No. 561), dial gauges (No. 854) and micrometers (No. 534), were set up; (4) New standards had to be fixed for such things as pinion-type cutters (Nos. 861–64), gear tools (No. 631), chucks (No. 561), abrasive grains (Nos. 314, 421, 554) and different bearings (Nos. 728–29, 747, 770–72), as the result of the development of various types of machine tools.

The standards were fixed by the technical committee for machine tools, which was generally composed of academics, engineers attached to large makers and the military, and the government officials concerned.³³ In the days of JES, various demands for standardization were often put forth by machine-tool manufacturer associations, whereas the requests from the military were given priority in the days of JES(T). What was more, in cases where standard were unavailable, army or navy standards were sometimes used as substitutes.

Japanese industrial standards, generally speaking, show the heavy influence of German standards (viz. DIN [Deutsche Industrie Normen] and Schlesinger's). Rather, we should say that Japanese standards were patterned after German standards. This implies that the technological levels required by Japanese standards did not remain far behind those of advanced countries. For instance, the allowable-error level in the JES(T) accuracy standards was not much lower than that of Schlesinger's, DIN, or NMTBA [National Machine Tool Builders' Association] standards.³⁴ From the negative point of view, the technological levels required in the new national standards, while serving as targets for the efforts of medium-sized machine shops, were beyond the capacity of tiny workshops, although they were considered reasonable for large machine-tool makers.

On the other hand, various policies to diffuse the national standards were promoted by the government as well. First, an official inspection system was established in 1939, with the result that various examinations as to machine quality became available almost without charge at the Machine Inspection Centers, which were located in five prefectures, viz. Tokyo, Osaka, Aichi, Shizuoka and Niigata. Secondly, the government began to promote the diffusion of JES(T)'s from 1940. Special exhibitions to propagate the national

³² Since the accuracy inspection standards are of greatest significance among the various machine-tool-related standards, we may specify their exact numbers and dates: lathes JES(T) No. 86, 1940; plain and universal milling machines No. 117, 1940; vertical milling machines No. 118, 1940; shapers No. 157, 1941; slotters No. 173, 1941; planers No. 174, 1941; radial drilling machines No. 244, 1942; horizontal boring machines No. 277, 1942; internal grinders No. 560, 1944; cylindrical and universal grinders No. 574, 1944; surface grinders No. 575–76, 1944.

³³ For the technical validity of selecting or converging to a standard, Eiichi Sasaki's paper ("Kōsaku kikai no buhin-kikaku nitsuite" [On the standards for machine-tool parts], *Nihon kikai gakkai shi*, Vol. 44, No. 290, May 1941) is very instructive.

³⁴ One may find the allowable-error comparisons for JES(T), DIN, Schlesinger's and NMTBA standards for the case of the lathe in the following papers: Sasaki, *loc. cit.*; Matsuda, "Kensa-kikaku"; and "Shiryō: NMTBA senban seido hyōjun-kikaku to Nihon hyōjun-kikaku tono hikaku" [Data: A comparison of JES and NMTBA standards for lathe accuracy], *Kōsaku kikai*, Vol. 4, No. 24 (Dec. 1941).

standards and educational campaigns through newspapers, radios and lecture tours were held frequently in major cities. Thirdly, the government finally decided to compel all large- and medium-sized machine shops to adhere to the national standards by means of the Special Law on Important Machine Manufacturers from 1941.

Each of these promotion policies was reasonably effective in its own way. However, what we judge to be the most effective means of popularizing industrial standards lay in other directions, namely price control (from 1939) and the subcontracting of munitions production. In the former case, the quality of each machine was specified fully at the time of freezing the price, as a matter of course. To meet this quality requirement, most machine-tool makers had frequently to adopt the JES(T)'s concerned. Similarly, in the case of the latter, the production of munitions even in small subcontracting workshops had to satisfy precisely the military standards. And the army's provisional standards and specifications were well known for their detailed nature. These requirements were, without doubt, the most powerful means to diffuse industrial standards throughout the machine-tool industry as a whole.

As is well known, an important aspect of standardization is the simplification of products. In the wartime development of the Japanese machine-tool industry, three different forms of simplification evolved: (1) cooperative design; (2) standardization of machine types; and (3) joint production. A valuable example of cooperative design is that of the famous "S-model" machine tools. In 1938 the blueprints of twelve S model machine tools were published by the government.³⁵ That is, the detailed specifications and engineering drawings of the twelve models, designed jointly by the engineers of the Big Five makers, the military and the ministries concerned over a period of three years, were offered virtually gratis (only a nominal charge of 10–30 yen) to any machine shop that wanted them.

The S-model machine tools were designed especially for the benefit of small- and medium-sized machine shops under the strong leadership of the government, on the assumption that the capacity of such shops for designing was quite poor. Despite this offer of blueprints, the machine quality required in the standard designs was said still to exceed the manufacturing capabilities of the small and medium workshops. This has been regarded so far as a reason for the unpopularity of the S models among them. Accordingly, we have examined the validity of this view of the quality of S models (for the case of lathes) by the pseudo-hedonic approach.

Based upon the data on prices, sizes (quantities) and grades for various machines,³⁶

³⁵ The S of "S models" stood for Shigen-kyoku [Resources Bureau], which took the leadership in this project. The blueprints of twelve models [step-cone-pulley-type lathes (2); all-gear-type lathes (2); radial drilling machines (2); an upright drilling machine (1); an all-gear-type plain milling machine (1); an all-gear-type universal milling machine (1); a step-cone-pulley-type plain milling machine (1); a step-cone-pulley-type vertical milling machine (1); and a shaper (1)] were published. Their detailed specifications are available in the appendix of *Mashinari*, Vol. 1, No. 7 (Sept. 1938). The idea of the cooperative design for S models was said to have originated from the lessons of VDF and ABMTM [Associated British Machine Tool Makers].

³⁶ The statistical data for our regression analysis are mostly based upon (1) the prices and the sizes of various makers' lathes, provided by the Central Price Committee in Oct. 1939; and (2) the grades as standardized in Nov. 1942. The sources are, respectively, *Nihon-kōsaku-kikai-kōgyō-kai* (ed.), *Hattatsu no katei*, pp. 202–205, and *Seimitsu kikai tōsei-kai kaihō*, Vol. 2, No. 5 (May 1943), pp. 4–5. These data are limited to the products of A-class makers. Our "pseudo-hedonic" approach means that a price is regressed on quantity variables, and the unexplained constant is interpreted as the quality factor.

we estimated the different constant terms for identifying different qualities by the ordinary least square method (see Table 5). Our prior information on the grade, i.e. junior, standard or quality machines, corresponds to the respective values of two dummy variables, namely $D_1=0, D_2=0$; $D_1=1, D_2=0$; or $D_1=0, D_2=1$. Consequently, if we insert the information for S-model lathes as to prices and sizes, the equation tells us from the best fit the grade, which turns out to be standard. This result endorses the commonly held view that the quality of S-model lathes lay between those of the Ikegai *D*-type and *K*-type (junior) lathes. In other words, the quality demands of S-model machine tools may have been too high for small-sized machine shops. Nevertheless, it is dangerous to conclude that the cooperative standard designs for S-model ended in failure, for many advertisements for the S-model machine tools may be found in industrial journals or directories.³⁷

Secondly, standardization of machine types was carried out for the lathe and the milling machine by the Ministry of Commerce and Industry in 1943. This selection was considered necessary for realizing the mass-production of standard machines of reasonable price and quality. Although production of the selected types was not legally compulsory, it was *de facto* compulsory by virtue of the government's controls over the distribution of materials in the wartime planned economy.

The third form of simplification, namely joint production, was the most powerful means in promoting specialization through simplification or standardization. In 1943 the government organized twenty-two emergency associations formed of more than a hundred first-rate machine-tool makers in major prefectures, in order to mass-produce the "wartime junior" lathes and milling machines.³⁸ Within the associations, each member specialized in producing parts or units for specified machines under the leadership of a parent assembly maker. Such subcontract-type associations were an extreme case of the joint production of completely standardized machines.

The effects of the last two forms of simplification on technological development of the industry are difficult to measure, since both were introduced almost at the last moment

TABLE 5. EVALUATION EQUATION FOR "S-MODEL" LATHES

$\log p = 6.895 + 0.792 D_1 + 1.026 D_2$					
	(49.45)	(10.95)	(14.26)		
				$- 1.365 x_1$	$- 0.296 x_2 + 0.851 x_3$
				(-1.82)	(-1.04) (4.03)
$R^{2*} = 0.966$					

Notes: 1) Variables are: p , the price of a lathe; D_1 , the dummy variable for the standard type; D_2 , the dummy variable for the quality type; x_1 , the center height of a lathe; x_2 , the maximum distance of centers; and x_3 , the bed length.

2) The above classification for grade follows basically the grade judgement applied by the Min. of Commerce & Industry in controlling the prices in 1939.

³⁷ To confirm the evidence, we examined the advertisements of one journal (*Kōsaku kikai*, Vols. 1-5) and one directory (*Seisan kikai taikan*, for the year 1941), both of which were typical sources of information for machine tools, and contained many advertisements. We found 8 makers of lathes, 9 makers of milling machines, 3 makers of drilling machines and 2 makers of shapers among the limited number of advertisers. All were medium-sized machine shops.

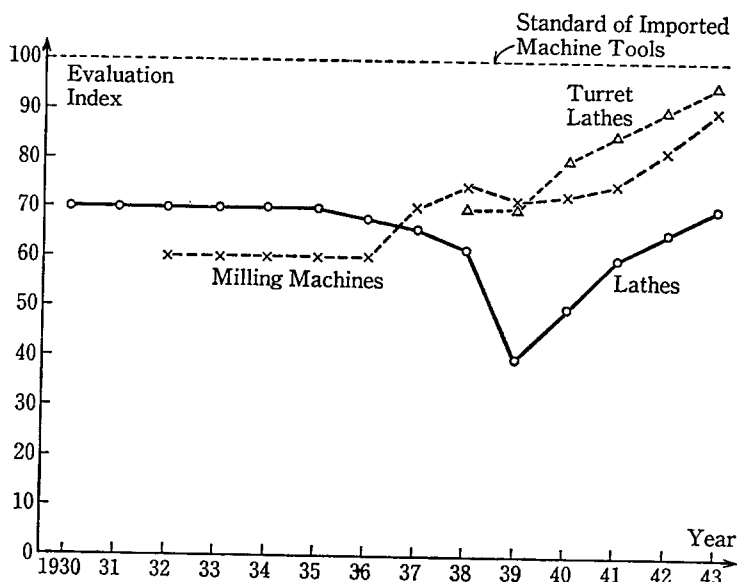
³⁸ These wartime junior machine tools were well-known for two features: (1) the unit-changeable system; and (2) single-function special-purpose machines with high performance.

of the Fifteen-year War, and were not fully implemented by the end of the war. What should be noted, however, is the fact that all three forms, including the S-model machine tools case, required as a precondition the prevalence of industrial standards. In other words, although we may hesitate to consider those simplification policies as fully successful, it may safely be claimed that their promotion at least facilitated the rapid diffusion of national standards throughout the industry.

4. Establishment of the Technological Basis

As is shown in Fig. 8 and Table 6, the quality of Japanese machine tools was greatly improved after the enforcement of the Special Law on Machine-tool Manufacturers, and particularly after 1939–40, the technological turning point defined by us.³⁹ While this upgrading of machine quality must be partly due to the energetic R&D activities of large makers, supported by the government's active subsidy policies, it is probably more attributable to the evolution of standardization. For the latter normally has greater effect on the improvement of the technological levels through the deepening of specialization and

FIG. 8. QUANTITY OF JAPANESE MACHINE TOOLS



- Notes: 1) Evaluation is an overall assessment relative to imported machine tools (100). It includes the assessment of the productivity, accuracy, durability and trouble frequency.
 2) The tests from which the data were derived were conducted at the Nakajima Aircraft Co.
 Source: M. Naruse, *Nihon gijutsu no botai* (Kikaiseisaku-shiryō-sha, 1945), pp. 52 and 166 [adapted].

³⁹ *Shōwa sangyō shi* [Industrial history of the Shōwa period], Vol. 1 (ed. and pub. by Tōyō-keizai-shimpō-sha, Tokyo, 1950) also holds the view that the quality of Japanese machine tools rapidly increased from 55 percent in 1937 to 90 percent of the foreign machine quality in 1943 (see, p. 389). Fig. 8, on the other hand, endorses a quality deterioration around 1938, said to be the result of mass production of inferior goods due to the munitions boom.

TABLE 6. EVALUATIONS OF TECHNOLOGICAL LEVELS OF JAPANESE MACHINE TOOLS

		Year	
Machine		1935	1944
1.	Lathes		
	a. Engine Lathes	62.7	86.5
	b. Turret Lathes	61.0	91.0
	c. Automatic Lathes	47.5	66.0
2.	Drilling Machines	61.2	85.0
3.	Horizontal Boring Machines	55.7	76.5
4.	Milling Machines	60.7	84.0
5.	Grinders	52.2	77.5
6.	Gear Cutters	55.0	79.0
7.	Special Purpose Machines	46.5	68.5
8.	Planers	55.7	68.5
9.	Shapers	59.0	86.0
10.	Slotters	55.7	77.5
Overall Average		56.0	78.8

Notes: 1) The evaluation is for Japanese machine tools relative to imported ones (100 pts).

2) The figures given are average scores of evaluations by 3 experts around 1935, and by 2 experts around 1944.

Source: Nihon-kōsaku-kikai-kōgyōkai, *Kōsaku kikai kōgyō sengo hattenshi*, Vol. I (Kikai-shinkō-kyōkai, 1984), p. 116.

competition, especially when the industry remains at the stage of imitative technology. That is, standardization is at least a necessary condition for the upgrading of technological levels.

We consider that Japanese national standards almost fulfilled this role once JES was reorganized into JES(T), since a JES(T) was swiftly set up whenever any basic standard (e.g. for machine elements) was required. Among various JES(T)'s, particularly the accuracy inspection standards for machine tools which approached the international level, played an important role in improving the quality of machines produced by medium-sized machine shops. Ironically, the infiltration of those industrial standards was promoted most powerfully by price controls and the requirements of munitions production.

As the result of the steady diffusion of machine-tool standards, specialization and interchangeability of machine elements and parts progressed rapidly. The intensive production of unit-changeable special purpose machine tools in the years 1943-44 symbolized the deepening of interchangeability in the industry. Similarly, it is possible to find various pieces of evidence for the evolution of specialization. For instance, it is well known that in the production of the fine boring machine by Ikegai in 1942, many important parts such as bearings, belts, chains, clutches, meters, oil-system-related parts, electric parts, etc. were obtained from outside special manufacturers.⁴⁰ The statistics of the Precision Machine Control Association also bear witness to the rapid progress of specialization in certain specific machine classes by small- and medium-sized machine shops. That is, the great majority of shapers, slotters, planers, grinders and gear-cutters were already being produced by them in 1943.⁴¹

⁴⁰ See, for example, Chokki, *Hatten katei no bunseki*, p. 178.

⁴¹ See Toyoji Hayashi, "Tōkei sadan (1)" [On some statistics (1)], *Seimitsu kikai tōsei-kai kaihō*, Vol. 2, No. 6 (June 1943), pp. 41-44. This work also reveals that large makers concentrated on the production of quality machines, such as jig boring machines, fine boring machines, thread grinders and tool room lathes.

These facts do not in the least imply an absence of difficulties in the Japanese machine-tool industry. On the contrary, its technological development had various limitations. The quality and size of engineering staff were inadequate. Quality control in the production process was still very primitive in general. The quality of raw materials (e.g. steel) was not at all satisfactory from the viewpoint of durability. Even the technological levels required for the standardization of machine tools were still wanting. For instance, the JES(T) system had no dynamic accuracy inspection standards, even though it established the static standards which had a less substantial meaning in comparison with dynamic ones. Finally, the timing of the setting up of standards was generally too slow as compared with the development of the industry (see Fig. 2). The typical example is the fixing of jig-related standards only in 1945.

None of these shortcomings are to be denied. Nevertheless, we are inclined to give a relatively positive estimation of the role played by standardization in the historical development of the Japanese machine-tool industry. For standardization greatly contributed to almost overcoming the three problems or difficulties described on p. 142. That is, national standards, attended by reorganization of the production system, definitely enabled the machine-tool industry to catch up to a certain extent with the technological levels of Western advanced countries.⁴² By the mid-1940's, the Japanese machine-tool industry can be considered to have almost outgrown the stage of imitative technology, mainly through the improvement of machine quality. Industrial standards facilitated this by (1) instituting explicit quality-standards; and (2) promoting specialization and competition due through the deepening of interchangeability or standardization. According to our definition of the term, this kind of upgrading of inferior imitative technology should also be regarded as an aspect of development of appropriate technology.⁴³

The above discussion has not gone into the various inefficient aspects of the wartime planned economy in detail despite the availability of a good deal of evidence. For such inefficiencies have hitherto been given sufficient emphasis elsewhere, although the references have not necessarily been systematic or analytical. Conversely, some positive aspects of the economy of the time have consciously been disregarded for ideological reasons. This is why we should like to point out the rapid technological advancement in Japanese machine tools mainly due to standardization during the Fifteen-year War. The remarkable development of the Japanese machine-tool industry in the postwar period becomes understandable only when we recognize the establishment of the technological basis for the machine-tool industry during the war. That is to say, the fact that the industry could undertake many licence agreements with Western advanced countries in the 1950's, and move on to extensive

Large-, medium-, and small-sized workshops are defined there according to the installed numbers of machines: more than 200, 200-101 and 100-20 machines, respectively.

⁴² Kiyoshi Mori points out the renovation of the management system in small- and medium-sized machine shops for purpose of upgrading machine quality during the war, in Hoshimi Uchida (ed.), *Gijutsu no shakai-shi* [A social history of technology], Vol. 5 (Tokyo: Yūhikaku, 1983), Chap. 4. Vivid descriptions of the situation prior to this renovation can be found in Yoshiharu Kiuchi, "Kikai kōgyō niokeru shōkibō kōjō no jissō" [Realities of small-sized machine shops], *Shakai seisaku jihō*, No. 188 (May, 1936).

⁴³ In the conventional sense as well, the S-model machine tools and the "wartime junior" machines were themselves typical appropriate technologies for pulling up the quality of inferior appropriate technologies.

adoption of quality control and Japanese Industrial Standards (JIS; the successor of JES) in the 1960's is to be interpreted as the result of a continuous development.

(Continued to the next issue)

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